§15. Particle Simulation of Collisionless Driven Reconnection in a Two-dimensional Open System

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Collisionless magnetic reconnection is an important process in a high temperature and rarefied plasma, such as the space plasma and the fusion plasma. In order to investigate nonlinear evolution of collisionless reconnection in an open system, a two-dimensional particle simulation code is developed on the basis of the previous one[1], in which the periodic boundary condition is used for a downstream boundary.

The simulation model is in the followings. The simulation domain consists of 256×128 grids. The driving electric field is assumed at two input boundaries so that the plasma flux is supplied with **E**×**B** drift velocity. The downstream (x-axis) boundary is an open one, across which particles may go into or out of the domain. The total number of particles is 1.6 million, half of which are assigned to an initial MHD equilibrium profile.

An electric field at the downstream boundary is determined by the free boundary condition ($\partial_x \mathbf{E} = 0$) to enclose the Maxwell equations, while the magnetic field can be automatically solved. The boundary condition for particles is illustrated in Fig. 1. For the open boundary, the number of outgoing particles can be calculated, while ingoing particles are required to be defined. So we calculate the average fluid velocity of region I in Fig. 1 to obtain the net number of particles passing across the boundary 1 during Δt

$$N^{net} = n < \mathrm{v} > \Delta t L_y$$

and then use the charge neutral condition to give the number of ingoing electrons and ions

$$N_{e1}^{in} = N_{e1}^{out} - N^{net}, \qquad N_{i1}^{in} = N_{i1}^{out} - N^{net}.$$

The velocities and positions of the ingoing particles are defined by using the information of particles passing across surface 2.

The contour plots of z-component vector potential at four different time periods are shown in Fig. 2 for the driving field $E_0 = 0.04$. Figures. 3 and 4 plot the temporal evolutions of the reconnection electric field $E_z^{(1)}$ and number densities (solid line for electron and dot for ion) at midpoint which is close to the reconnection point. The reconnection is triggered around time step 5000 just when the densities reach their maximum. Here one time step Δt is about 0.02 ω_{ce}^{-1}. Then the reconnection electric field rapidly grows up until the densities drop to a steady value at about step 10000. From this time on, the reconnection gradually approaches to a saturation level and tends to get to a steady state.

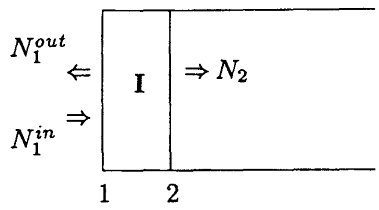

Fig. 1. Illustration of the boundary condition for particles.

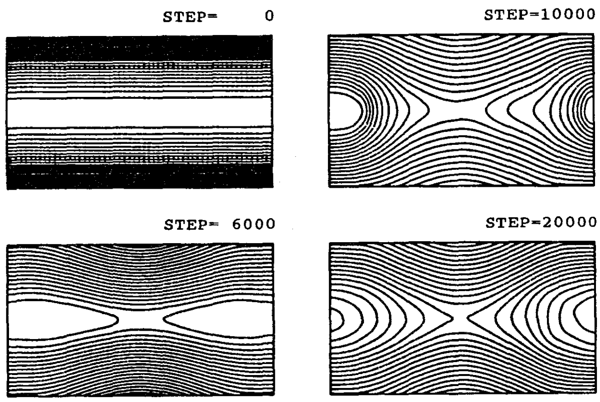

Fig. 2. The four snapshots of z-component vector potential.

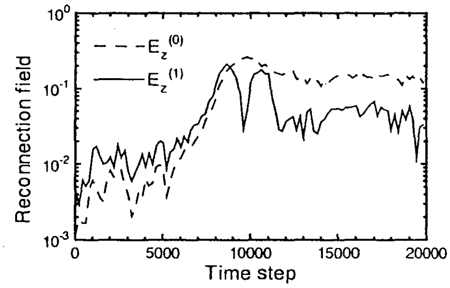

Fig. 3. The temporal evolution of Fourier modes of reconnection electric field.

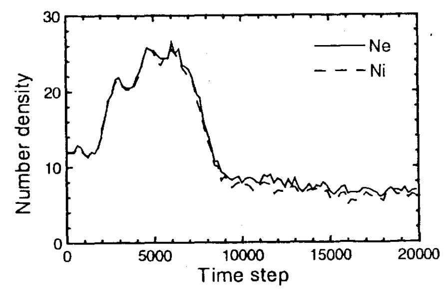

Fig. 4. The temporal evolution of electron and ion densities at the mid point.

Reference

1) Horiuchi, R., Sato, T., Phys. Plasmas 4, (1997)277